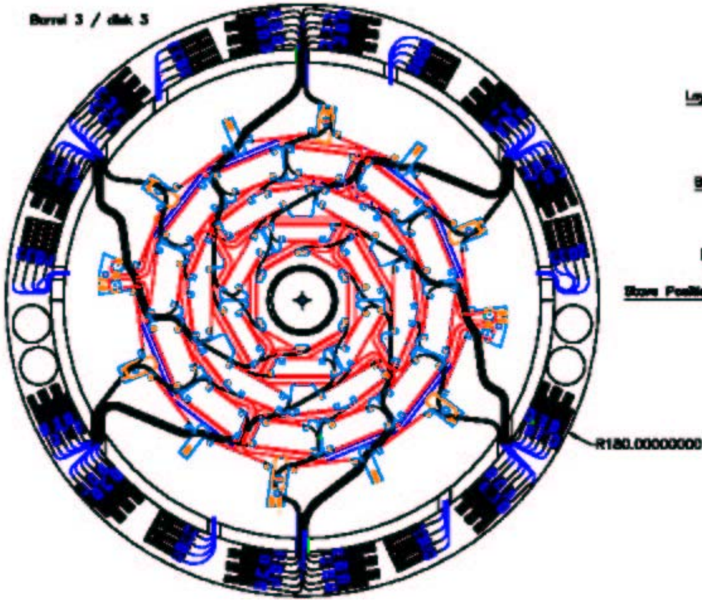
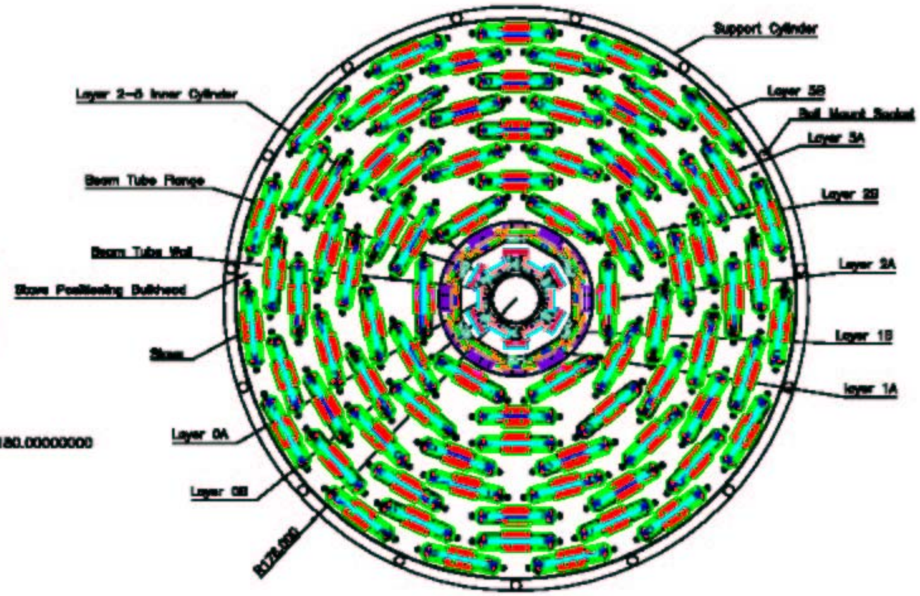
Run IIb Silicon Mechanical Design

- Run IIa and IIb geometries
- Sensor dimensions, numbers, and drawings
- Hybrids, layouts, and drawings
- Layer 2-5 staves and cooling
- Layers 0 and 1: geometry, cooling, and materials
- Summary

W. E. Cooper, Fermilab

Silicon End View (Barrels)

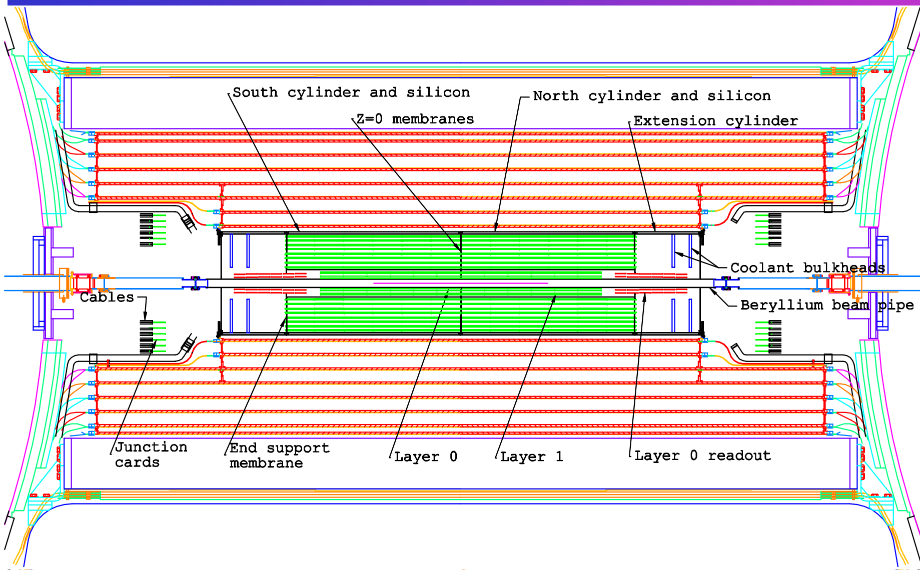


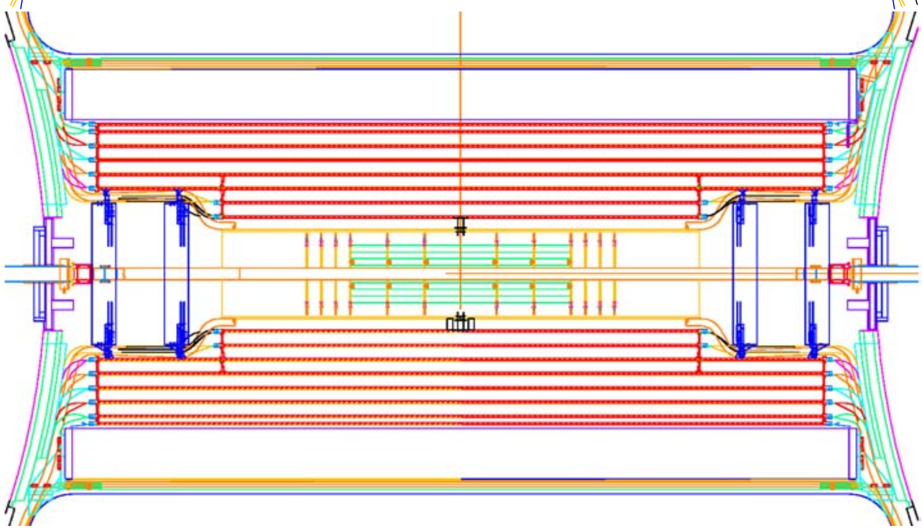


- Run IIa barrels:
- 1.3 m^2 silicon
- 4 layers
- 864 sensors
- Double-sided except for layers 1 and 3 of the outermost barrels

- Run IIb barrels:
- 8.6 m^2 silicon
- 6 layers
- 2304 single-sided sensors
- Stereo and axial sensors in layers 2-5, axial only in layers 0-1

Plan View





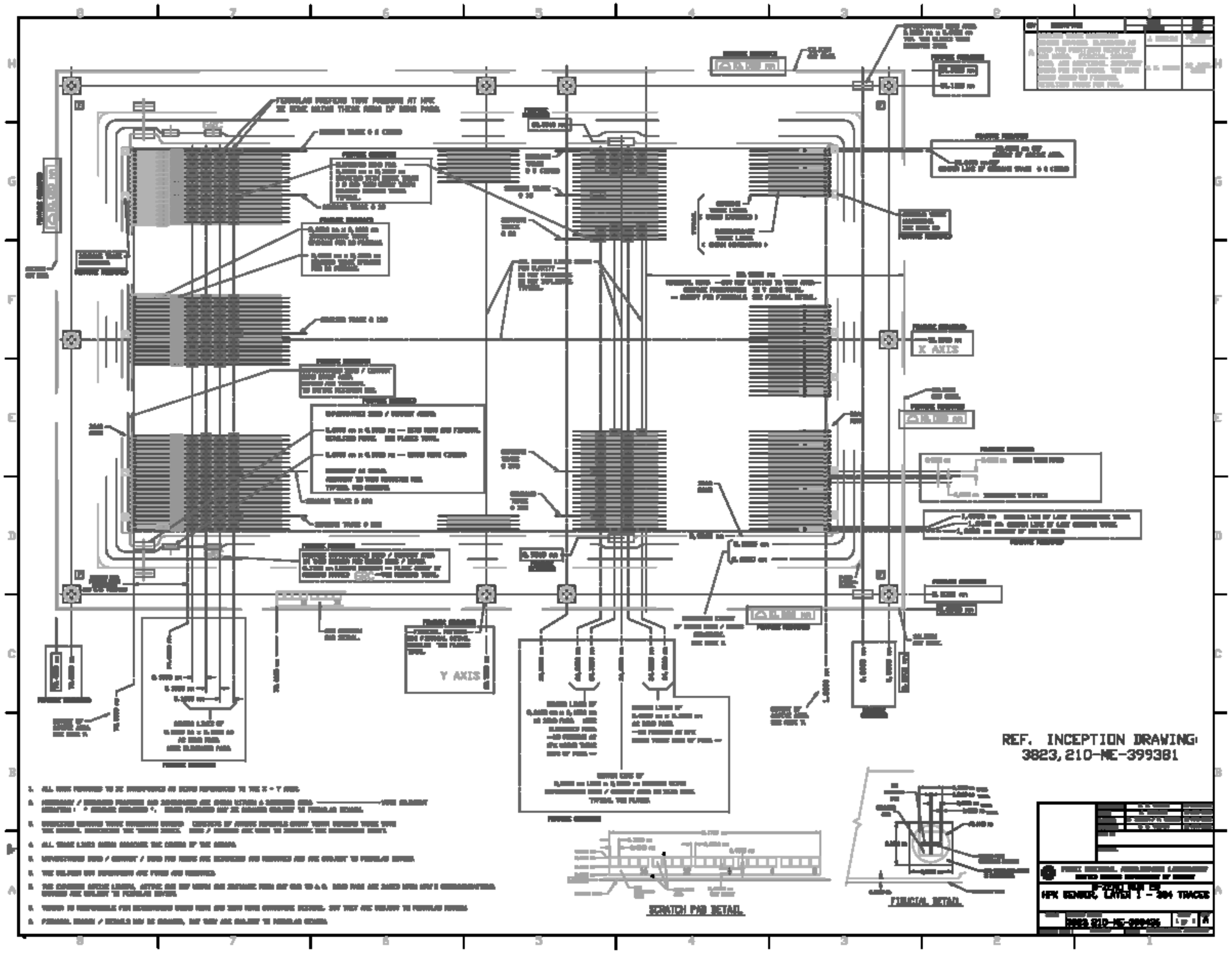
- Run IIb:
- 18.542 mm IR beam tube
- 12 sensors long (all layers)
- L0 - L1: 8 cm sensors
- L2 - L5: 10 cm sensors
- 1220 mm long barrel region
- Support from "bulkheads" at z = 0 and z = ±610 mm

- Run IIa:
- 14.224 mm IR beam tube
- Six barrels, twelve F-disks, four H-disks
- 1070 mm long barrel plus F-disk region

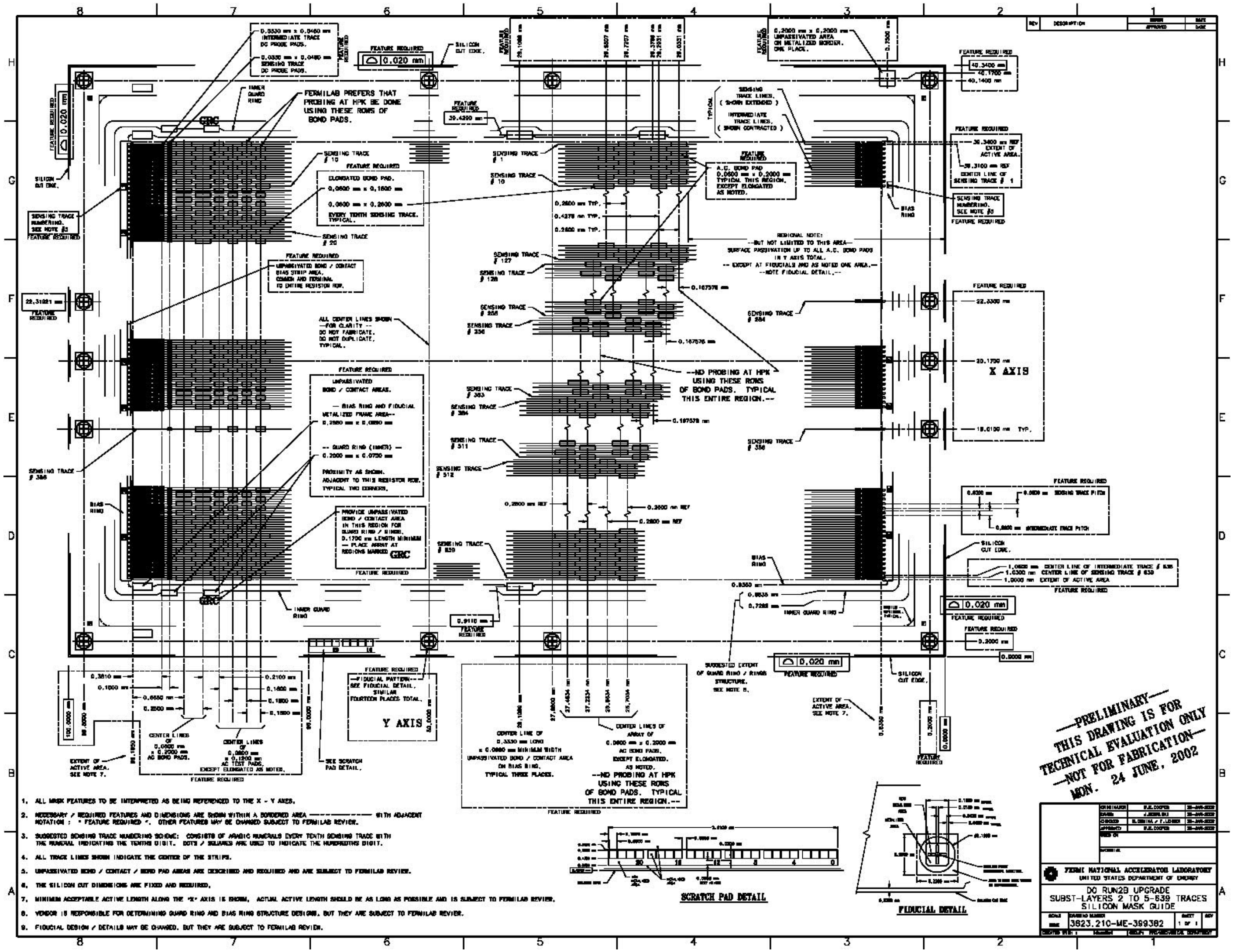
Sensors and Sensor Drawings

- The L1 sensor drawing was submitted to Hamamatsu (HPK) and revised to take into account HPK fabrication requirements.
  - The cut dimensions are 24.312 mm wide x 79.4 mm long (384 readout traces, 0.058 mm readout pitch, intermediate strips).
  - L1 has axial readout only.
  - For comparison, the 3-chip wide sensors of Run 2a have cut dimensions of 21.2 mm x 60 mm, 0.050 mm readout pitch, and no intermediate strips.
- The L2-L5 drawing has been submitted to HPK.
  - Cut dimensions are 40.34 mm wide x 100 mm long (639 traces, 0.060 mm readout pitch, intermediate strips).
  - The odd number of traces is needed to allow sensor-sensor bonds.
  - All L2-L5 sensors are identical. Stereo angles are obtained by rotating sensors.
  - For comparison, the 5-chip wide sensors of Run 2a have cut dimensions of 34 mm x 60 mm, 0.050 mm readout pitch (axial surface), and no intermediate strip.

L1 Sensor Drawing



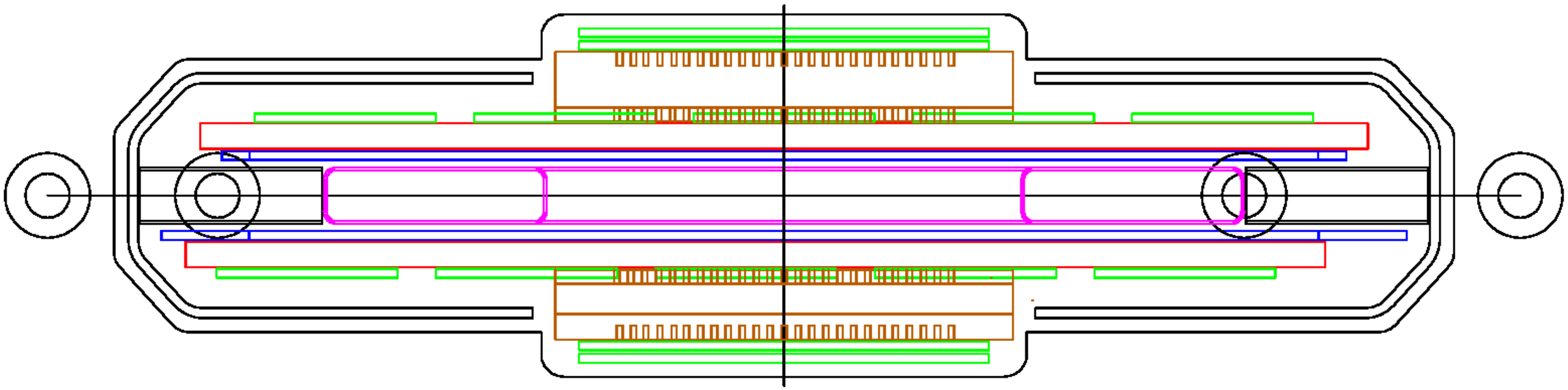
L2 – L5 Sensor Drawing



Sensors and Sensor Drawings

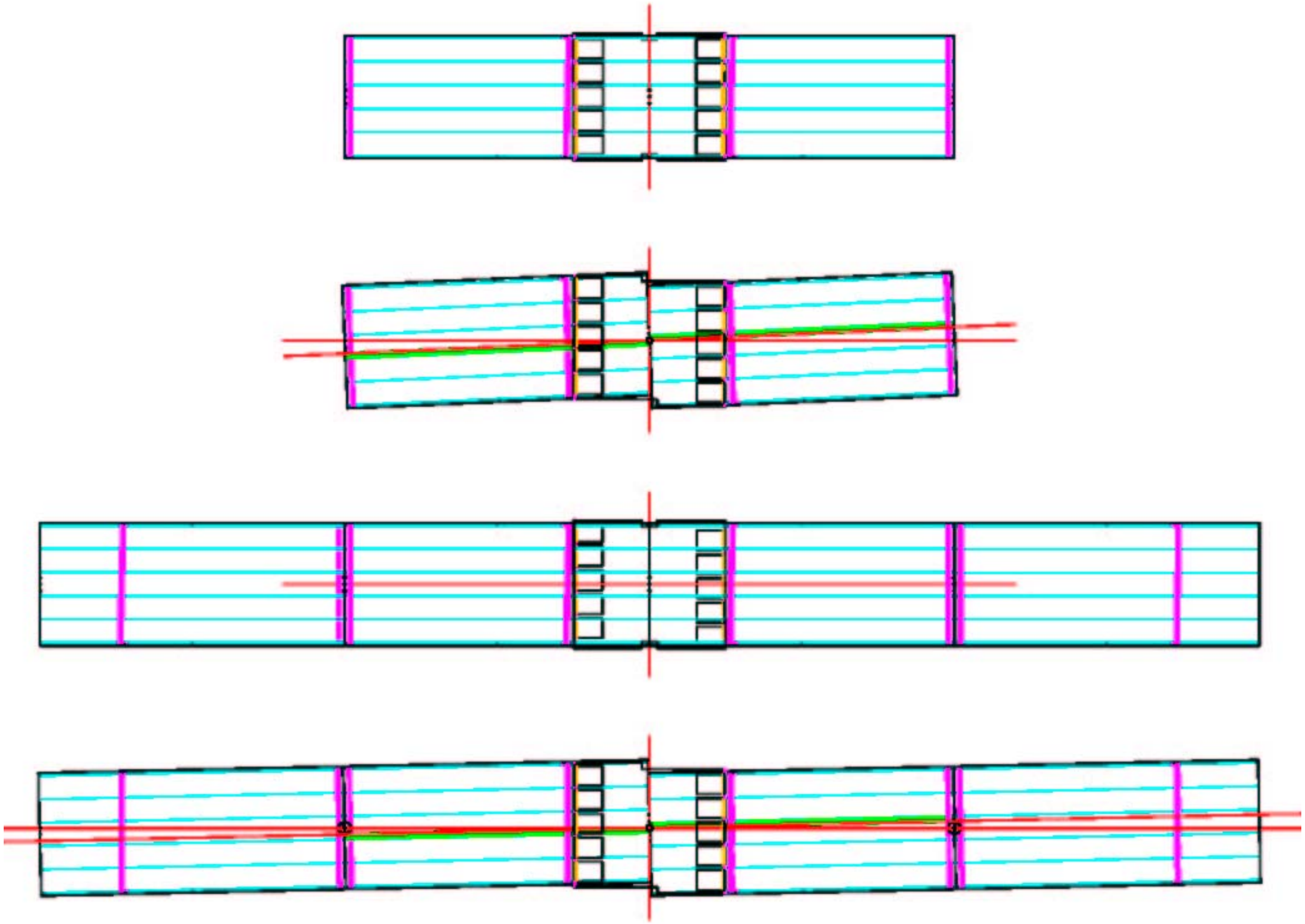
- A L0 sensor drawing is in preparation following the format of the L1-L5 drawings.
  - The proposed cut dimensions are 14.84 mm wide x 79.4 mm long (256 traces, 0.050 mm readout pitch, intermediate strips).
  - We have verified that CDF L00 masks could be used instead of the L0 sensor layout developed for D0, if one trace of 256 were not read out.
  - L0 has axial readout only.

L2-L5 Stave End View



- In this picture (L3 or L5), the axial sensors are on the top surface and the stereo, on the bottom.
- In L2 and L4, the opposite stereo sense is obtained by rotating the staves 180° about their longitudinal axis. L2 and L3 staves are identical as are those of L3 and L5.
- Digital cables run along the stave outer surfaces from connectors on the hybrids to (and beyond) the z = 605 end of each stave. All cooling connections are at the z = 605 mm end.
- Z = 0 pins are offset so that the pins of north silicon miss those of south silicon.

Hybrid – Sensor Layout



200 mm axial

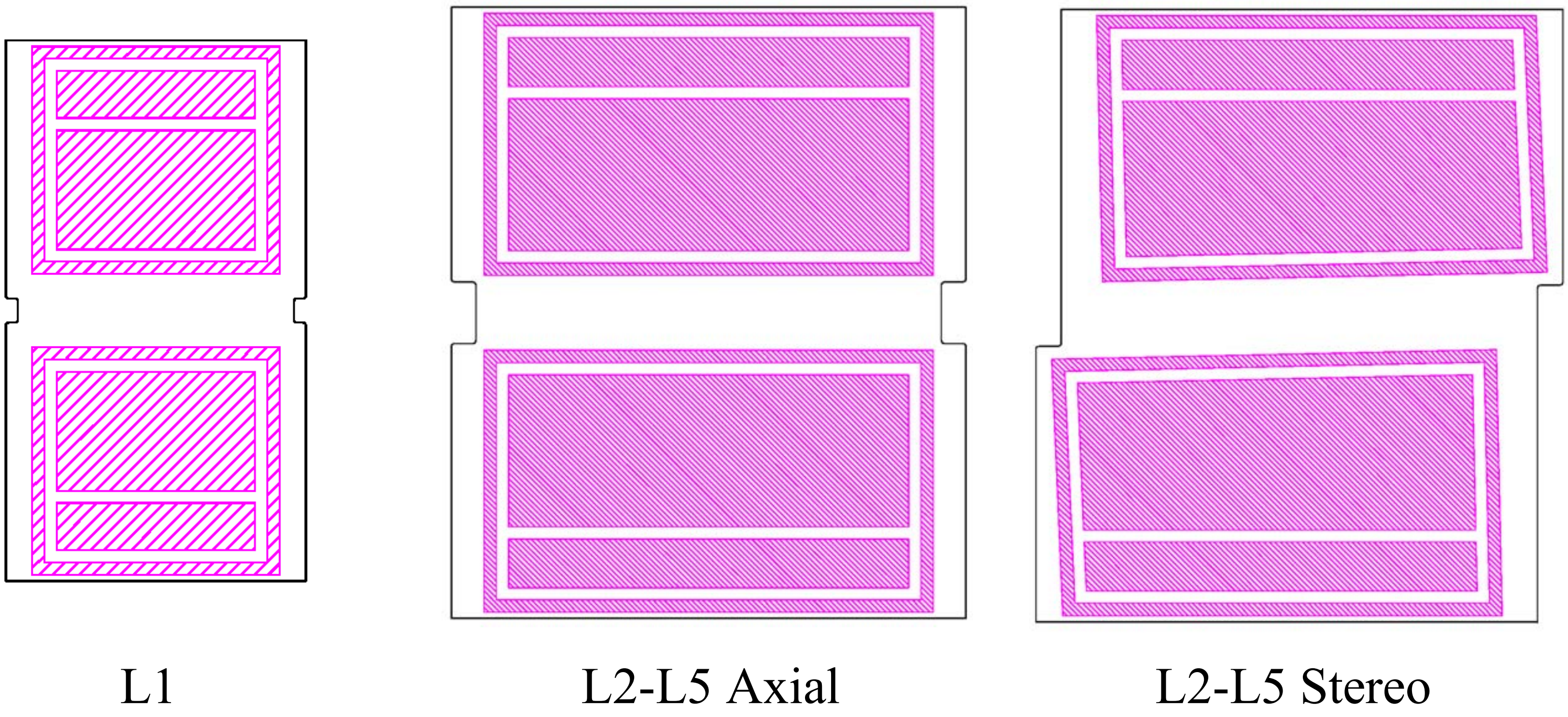
200 mm
2.48° stereo

400 mm axial

400 mm
1.24° stereo

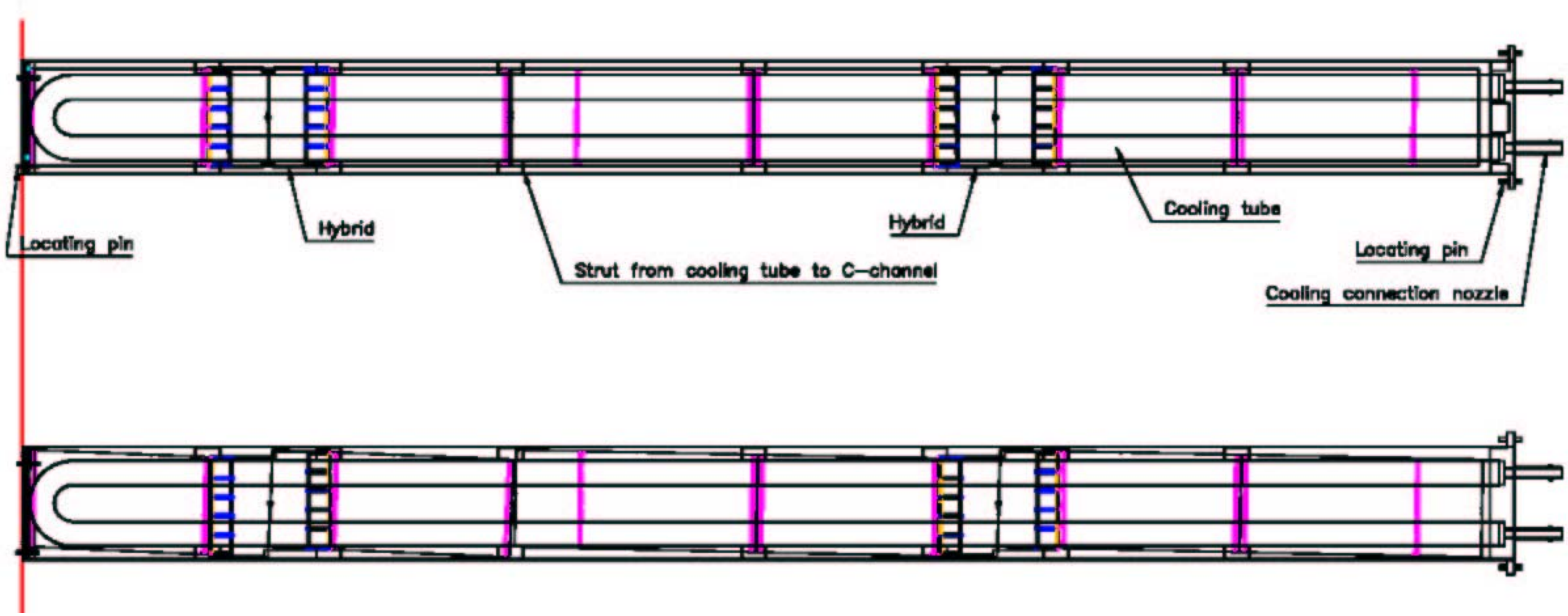
Hybrid Backside Printing

- Aids in controlling hybrid flatness
- Aids in preventing epoxy flow onto sensor guard ring during sensor – hybrid module assembly



Plan View of Staves

Both views are with axial surface up.



- Axial view at top
- Stereo view at bottom

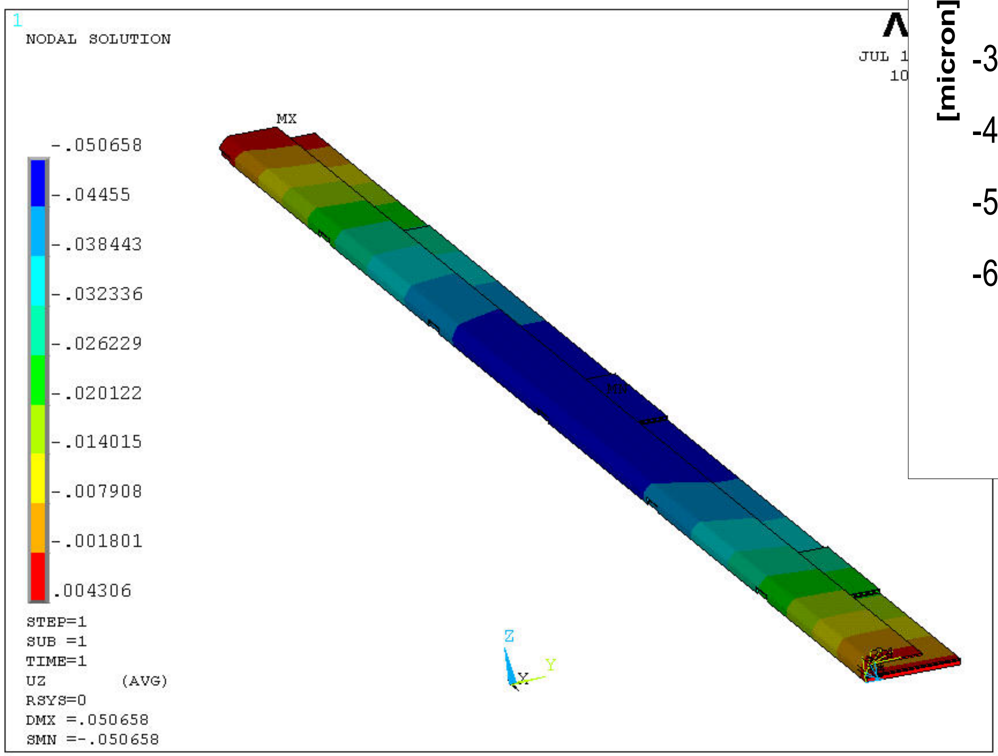
FEA for Staves

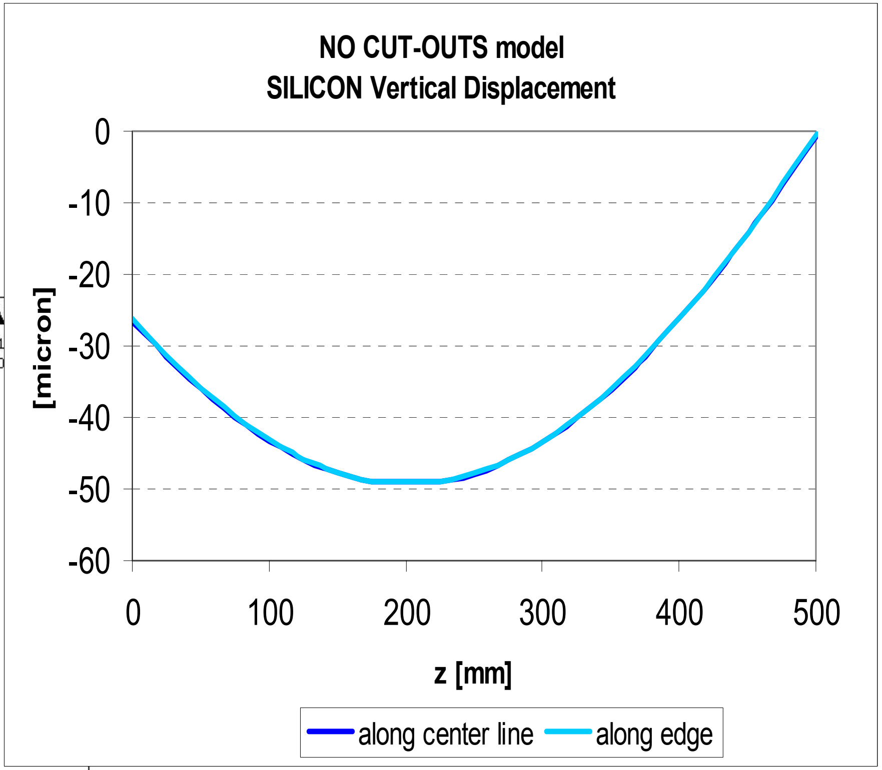
Units in mm

Restraints on 4 end node

z = 0mm, free to slide longitudinally

z = 600, clamped





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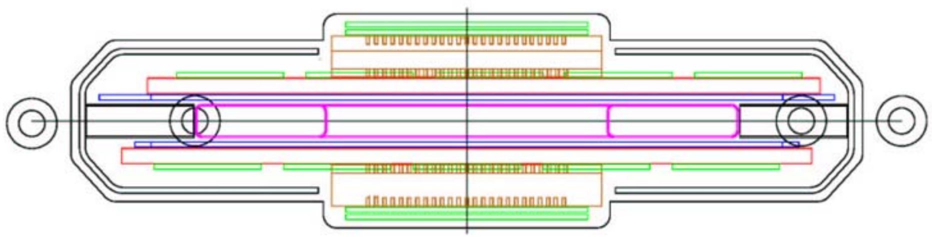
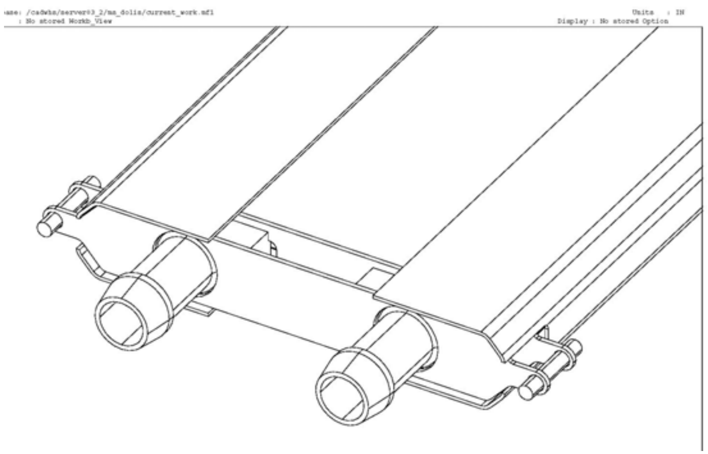
Mechanical Tests of Staves

- FEA calculations of deflections under load have been verified by measurements
- Natural resonant frequency calculated to be about 87 Hz
- Stave structure is basically symmetric about neutral plane, which eliminates thermal bowing
- Checks for thermal stability will be made by thermal cycling a small number of staves

Cooling Tubes





- L2 – L5 Staves:
- Stiff core based upon carbon fiber cooling tubes
  - Fixes relative transverse positions of the four axial and stereo hybrid - sensor modules of a stave
  - Fixes radial separation of axial and stereo silicon
  - Ties into C-channels which provide out-of-plane stiffness to stave
  - Integrates cooling tube with nozzles, C-channels, and stave locating features at ends

Cooling Tubes

- Advantages of carbon fiber:
  - Allows leak checking to full vacuum both prior to and after silicon is mounted on the stave core
    - Leak checking does not pose a hazard to the stave
    - Leak checking can be performed at SiDet and later at DZero
    - Essential for a leak-free cooling system
  - Compatible with many adhesives
  - Secure and reliable connection between cooling tube and its nozzles
  - Sensor-hybrid module support within the stave is with a single low CTE material and is geometrically balanced against bowing
  - Relatively straight-forward fabrication of low-height cooling tubes needed with C-channel stave design
  - Stave deflection under gravity is low with C-channel design (50-60 μm)

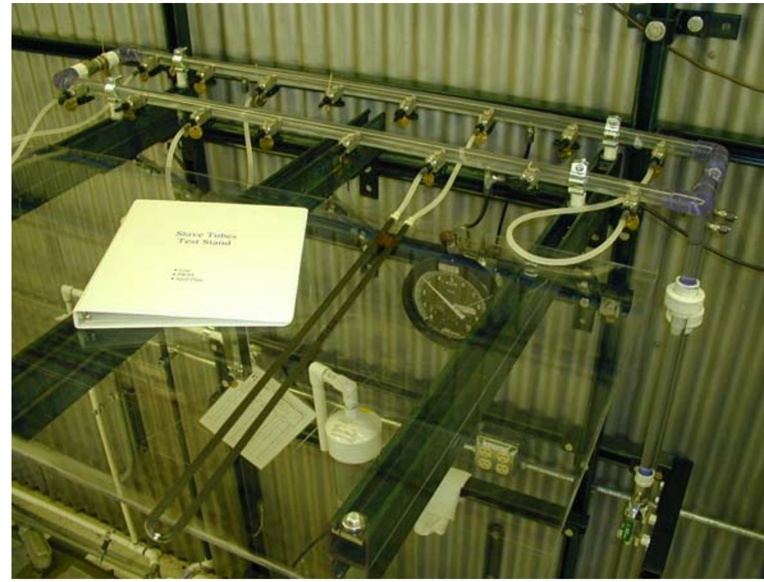
Cooling Tubes

- Other considerations:
  - Reasonable thermal conductivity in plane of fibers (150-200 W/m*C)
  - Acceptable thermal conductivity normal to plane (0.8-2.0 W/m*C)
  - Good radiation hardness (500-1000 Mrad with cyanate ester resin)
  - Low moisture absorption with cyanate ester resin (0.04%)
- Disadvantages
  - Should be grounded at hybrids (Method has been developed)
  - Long-term testing needed to verify that leaks will not develop (Testing is underway)
    - Determination of time-scaling with temperature (ASTM)
    - Testing well beyond the operating temperature range

Cooling Tubes

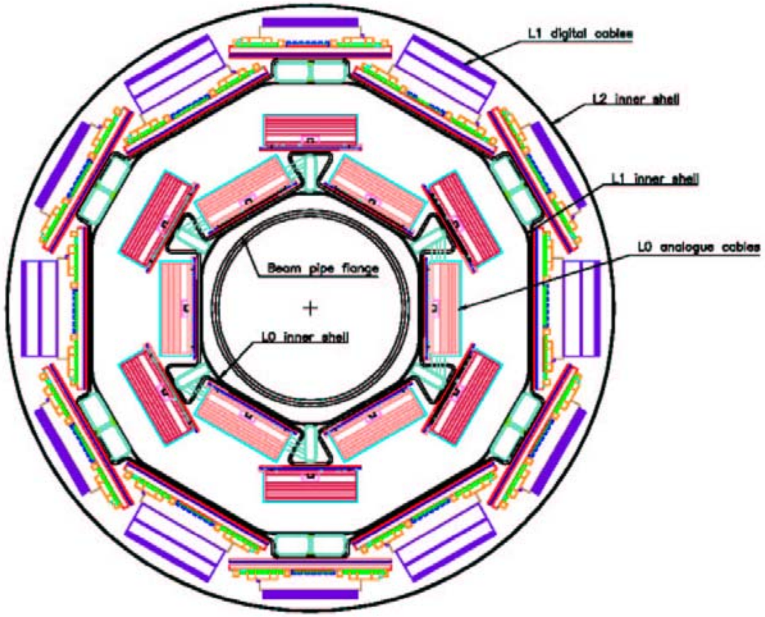
- L0 – L1
  - Most of the same considerations apply, but
    - Matching CTE's is a greater issue
    - Heat transfer is a greater issue
    - Carbon fiber cooling tubes are used structurally to support L0 hybrids

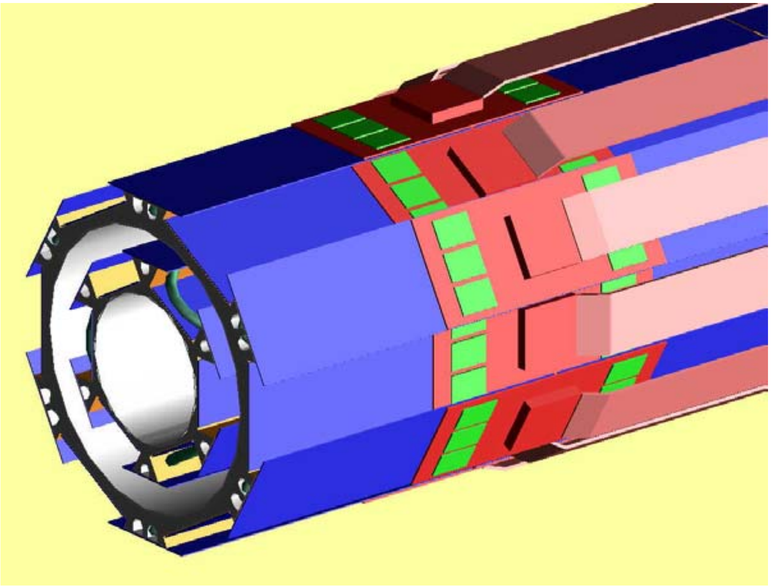
SiDet Cooling Tube Test



- Sub-atmospheric operation with 41% ethylene glycol in water
- 13.7 psia supply pressure is set by elevation
- 3 psid across tubes corresponds to final operation
- Flow rate is increased due to room temperature operation
- Test system configured to accept both a heater and a chiller

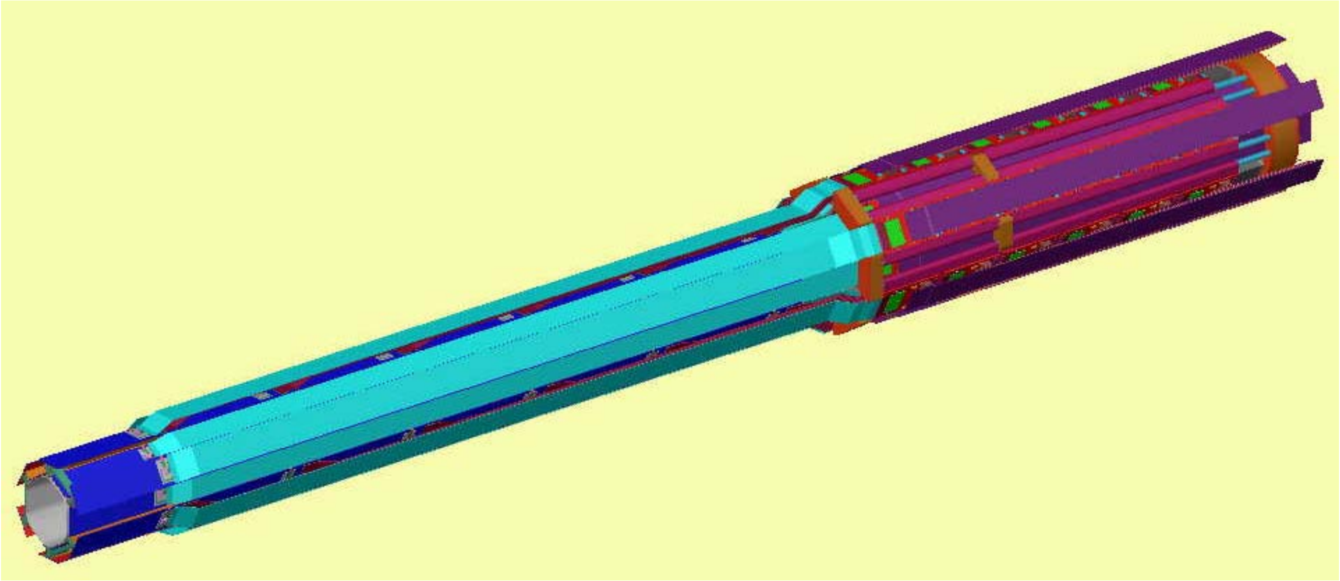
L0 - L1 (University of Washington)





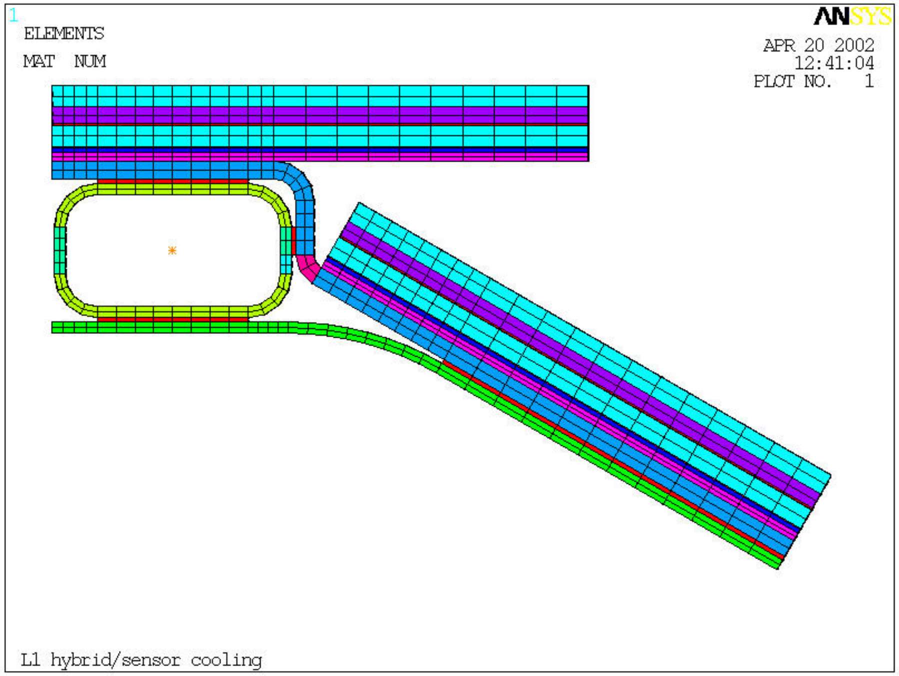
- Sensors at twelve azimuthal positions and two radii for each layer
- Support is via carbon fiber reinforce epoxy cylinders
- The outer cylinder is castellated to provide the two radii
- The inner cylinder is either round or hexagonal
- Support for the cylinders is at z = 0 and z = 61 cm

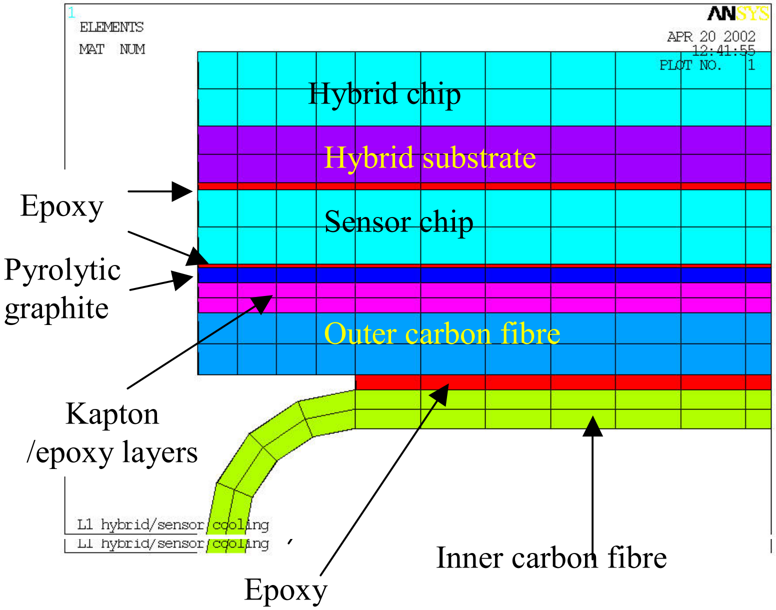
L0 Geometry



- Hybrids are located at the end of the sensor region and connected to the sensors via analogue cables
- Independent cooling is provided for the sensors and the hybrids to simplify heat removal from the silicon. A maximum silicon temperature below −10 C is easily achieved.

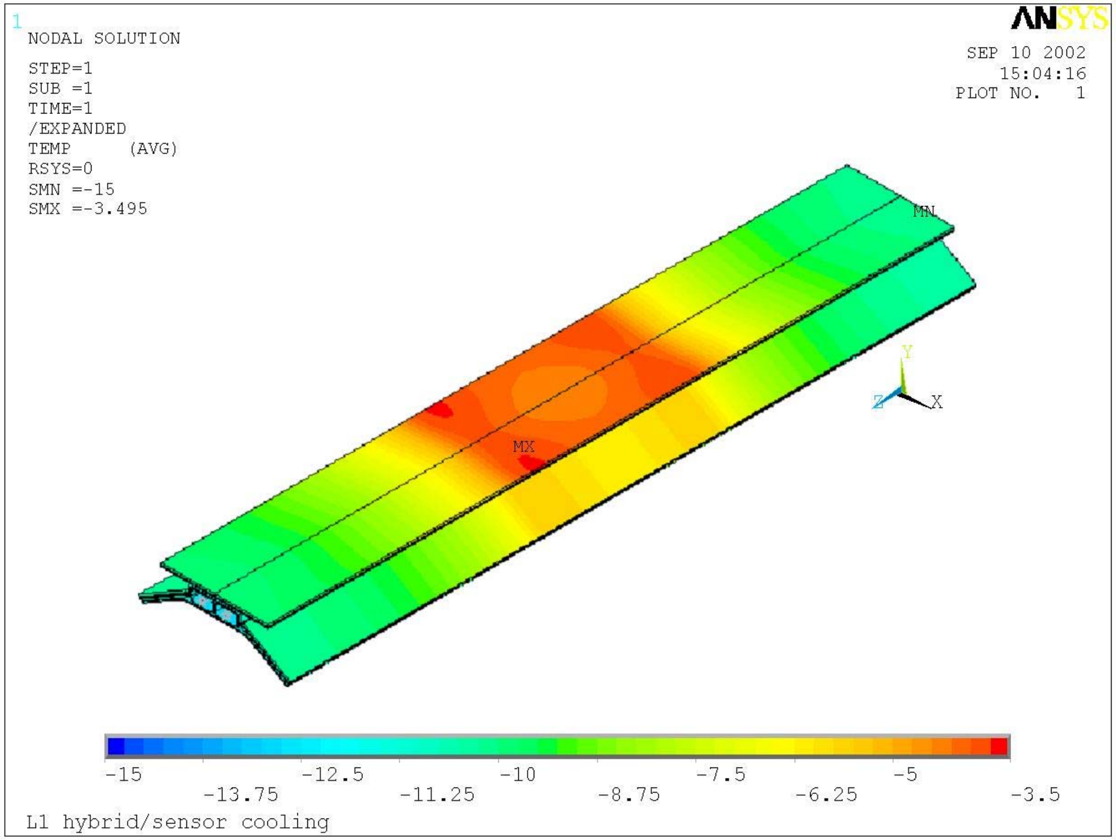
L1 Thermal Studies (UW)





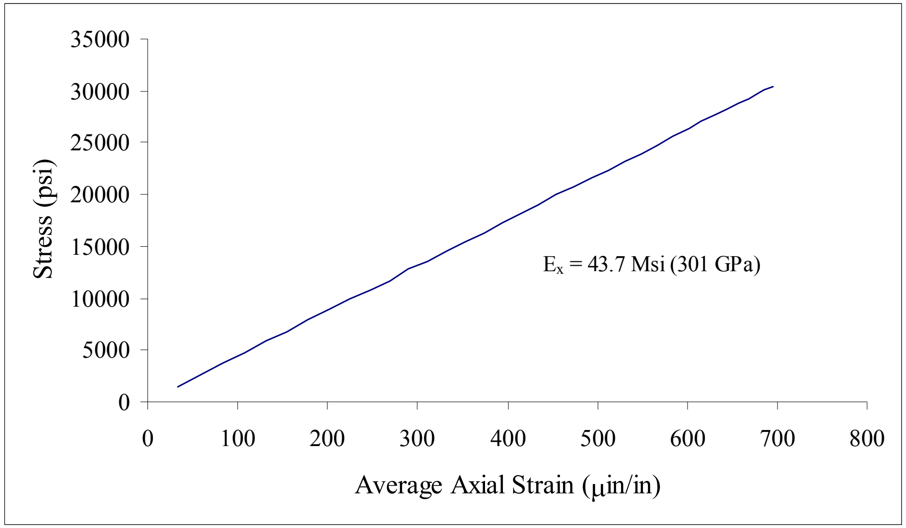
- Cross section showing the various layers of materials in the model. Note the use of a layer of pyrolytic graphite sheet under the sensors.

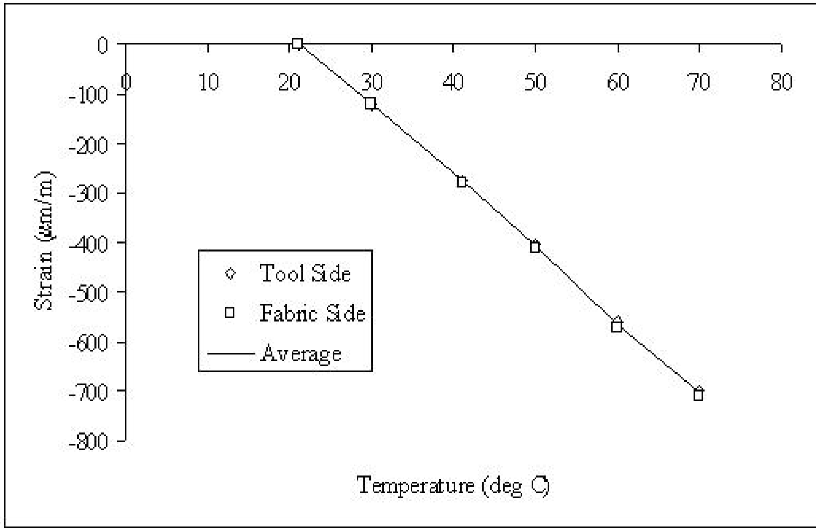
L1 Silicon Temperatures (Colin Daly)



Temperature map of L1 silicon sensors. The maximum temperature of L1a is –5.5 C; that of L1b is –3.5 C. An added heat load of 0.1 W/sensor would raise the maximum L1b temperature to –2.0 C.

L0 - L1 Carbon fiber





Modulus E_x measured for a $[0/20/-20]_s$ K13C/epoxy laminate

Thermal strains used to infer a_1 for K13C/Epoxy . Slope implies a_1 = -3.7mm/m-C

- Extensive and detailed studies of carbon fiber structural and thermal behaviors have been made by Mark Tuttle of the University of Washington.

Summary

- The Run IIb geometry has been established.
  - North and South barrels, each with six layers
  - Independent, but mating, structures for L0-L1 and L2-L5.
  - 122 cm long silicon region
  - Support from fiber tracker barrel 1 via extension cylinders
- L1 and L2-L5 sensor drawings have been prepared. Preparation of L0 sensor drawings is near completion.
- Stave designs with integrated cooling and positioning features have been developed for L2 – L5.
- Sensor – hybrid module designs have been developed which match the stave designs.
- Designs of support structures for L0 and L1 have been developed, along with matching hybrid designs.
- Finite element studies have been made of deflections and cooling for all layers.
- Mechanical prototyping and testing have progressed well.